High Resolution X-ray Fluorescence Microscopy: Challenges and Opportunities

S. Vogt[1,2*], S.-C. Gleber[1], S. Chen[1], L. Finney[1], J. Ward[1], J. Deng[2], R. Mak[2], D. Vine[1], L. Trahey[1], L. Makowski[3], T. Paunesku[2], C. Flachenecker[4], J. Maser[1], C. Jacobsen[1,2], B. Lai[1], K. Brister[2], G. Woloschak[2]

[1]Argonne National Laboratory, [2] Northwestern University, [3] Northeastern University, [4] Xradia Inc.,

Hard x-ray microscopy is a powerful technique to visualize structure and local chemistry of complex specimen. It is well suited to probe hard as well as soft materials, including biological specimens such as cells and bacteria. For medium to high Z material, characteristic x-ray fluorescence is used to visualize elemental content, with sensitivities down to attograms. Phase contrast allows one to sensitively detect specimen structure, and combine structural information of the sample with trace elemental content. Spatial resolutions of 200 nm are routinely achieved, 30 nm has been demonstrated. Typically, 10-15 elements are mapped simultaneously, leading to precise elemental colocalization maps. The large penetration depth of hard x-rays permit the analysis of 'thick' samples; by acquiring numerous 2D projections at different specimen angles, 3D elemental distributions can be reconstructed and visualized.

Because of low fluorescence yield, small photo electric absorption coefficients, and increased self absorption effects, low-Z material is difficult to visualize exploiting x-ray fluorescence. Instead, either differential phase contrast or Zernike type phase contrast in scanning geometry can be utilized to visualize (low-Z based) specimen structure, and combine structural information of the sample with (trace) metal content.

We will report on the capabilities of existing microprobes, including a cryogenic bionanoprobe with spatial resolution down to 30 nm that we recently installed and are commissioning. We will also discuss methods we have implemented, including data analysis, phase contrast techniques, fast fly-scanning, and X-ray fluorescence micro-tomography. We will demonstrate their application in several ongoing studies, ranging from the analysis of trace elemental contents in diatoms, to the investigation of nanocomposites as novel tools for cellular and intracellular targeting, imaging, and potential treatment, to the investigation of reactants and contaminants in the matrix and interface materials of batteries and catalysts.

We will also discuss challenges and opportunities for future scientific applications and instrumentation, in particular with regards to ever faster detectors, better optics, and improved data acquisition strategies, as well as the development of the *in-situ* nanoprobe at the Advanced Photon Source. This new beamline will be optimized for high resolution (20-50nm) X-ray microscopy in *in-situ* environments, permitting the control of relevant parameters such as temperature, gases and acidity.